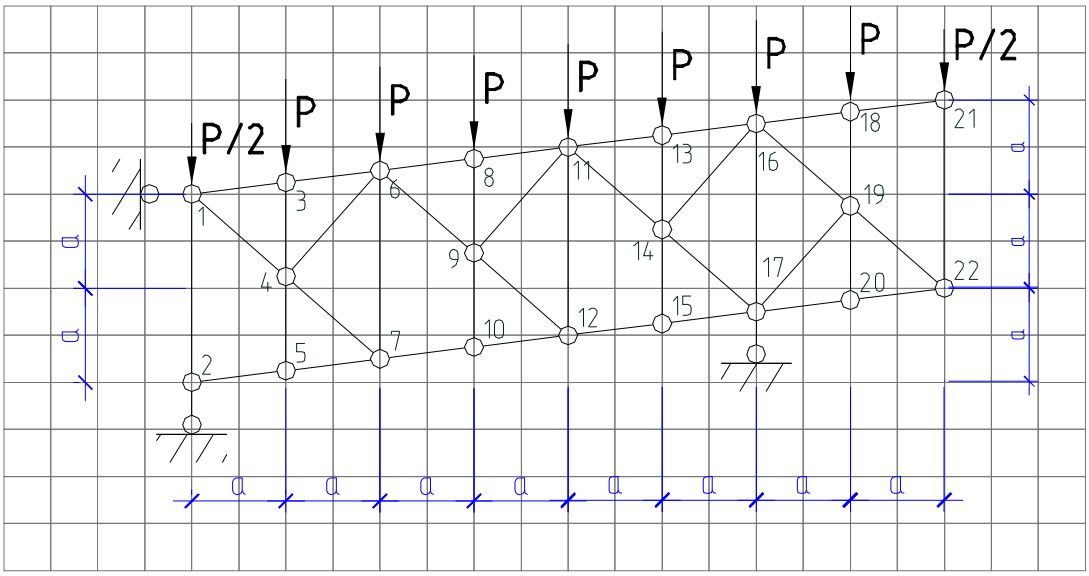
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Задача № 2. **Расчет фермы с треугольной решеткой аналитическим графическим способом.**

Заданная расчетная схема

1) Кинематический анализ

1.1. Количественный кинематический анализ

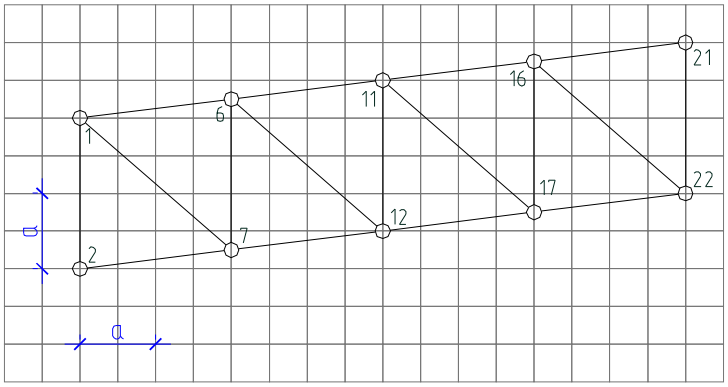


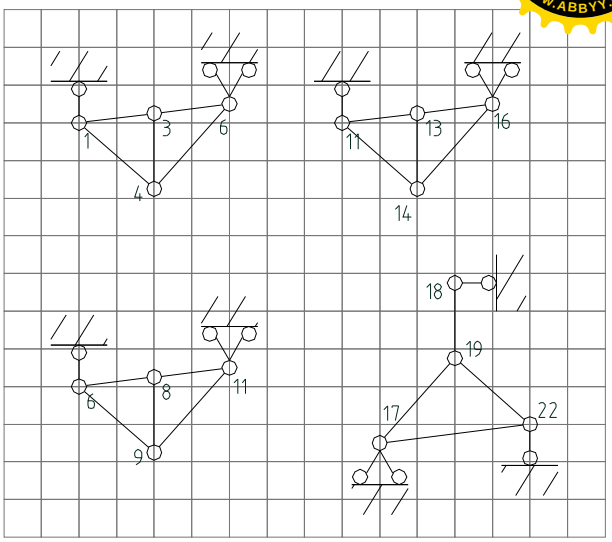
$W = 2У - S - C_0 = 2 \cdot 22 - 3 - 41 = 0 \Rightarrow$ ЗРС статически определима

					Контрольно-курсовая работа №2		
Изм.	Лист	№ докум.	Подпись	Дата	Расчет фермы аналитическим и графическим способом	Лит.	Масса / Масштаб
Разраб.		Мишкина Л.А.					
Провер.		Судакова И.А..				Лист 1	Листов 12
Т. Контр.							
Реценз.						ТулГУ гр.320863	
Н. Контр.							
Утверд.							

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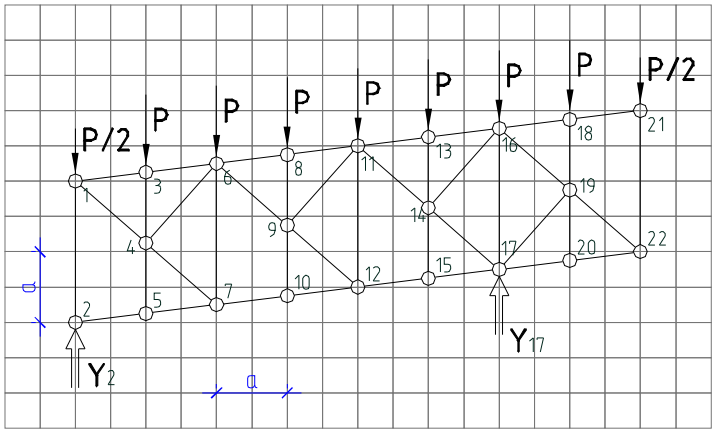
1.2) Качественный кинематический анализ





Т.к. решетка основной фермы и шпренгелей треугольная ⇒ каждая из них является геометрически неизменяемой, а значит и ЗРС геометрически неизменяема

2) Определение реакций в опорах и перераспределение усилий



$$\sum mom_{17} = 0$$

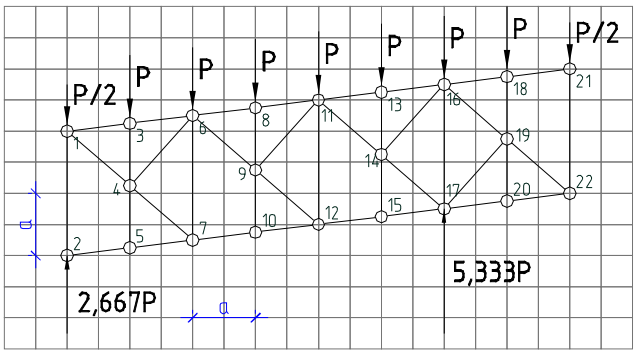
$$6aY_2 + 2aP + 0{,}5P \cdot 2a = aP + 2aP + 3aP + 4aP + 5aP + 6a \cdot 0{,}5P$$

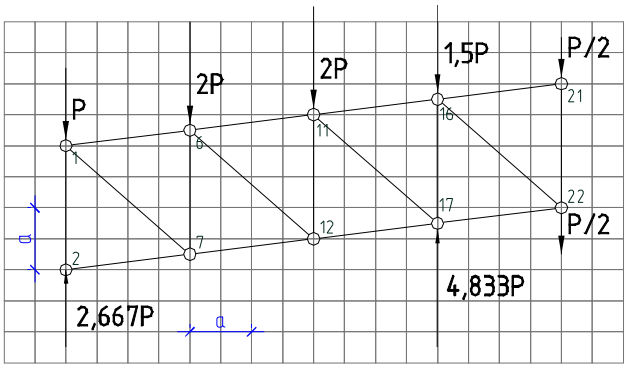
$$Y_2 = 2{,}667P$$

$$\sum mom_2 = 0$$

$$6aY_{17} = 8a \cdot 0{,}5P + 7aP + 6aP + 5aP + 4aP + 3aP + 2aP + aP$$

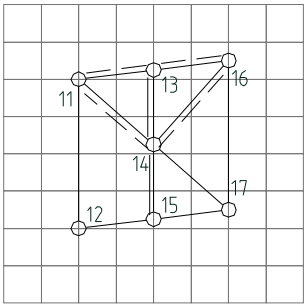
$$Y_{17} = 5{,}333P$$





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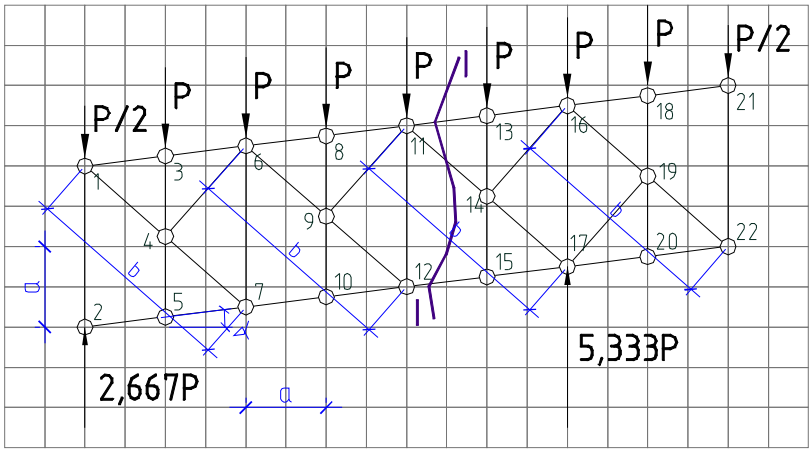
3) Классификация стержней 3 панели шпренгельной фермы.



I категория 12-15, 15-17, 17-14, 11-12
II категория 13-14, 14-16
III категория 11-13, 13-16, 11-14
IV категория 16-17

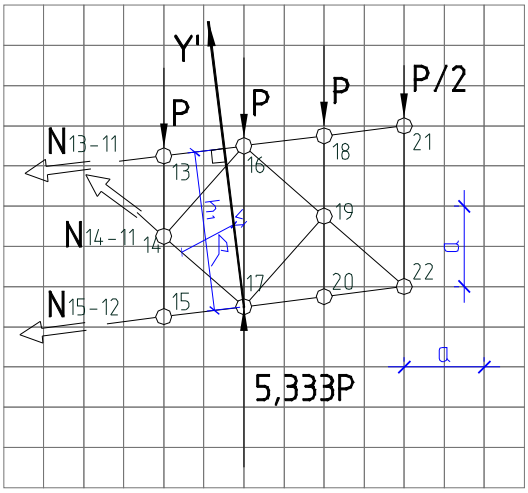
4. Порядок расчета фермы.

4.1. Метод сечений:



ЗРС

I-I



1. $N_{13-11} \Leftarrow \sum mom_{17}^{np} = 0$

$$P \cdot a - P \cdot a - \frac{P}{2} \cdot 2a + N_{13-11} \cdot h_1 = 0$$

$$h_1 = 2a \cdot \cos\alpha = 2a \cdot \frac{8a}{\sqrt{(8a)^2 + (a)^2}} = 2a \cdot 0{,}9923 = 1{,}9846a$$

$$N_{13-11} = \frac{Pa}{1{,}9846a} = 0{,}504P$$

2. $N_{15-12} \Leftarrow \sum mom_{11}^{np} = 0$

$$P \cdot a + P \cdot 2a + P \cdot 3a + \frac{P}{2} \cdot 4a - 5{,}333P \cdot 2a + N_{15-12} \cdot h_1$$

$$N_{15-12} = \frac{2{,}667Pa}{1{,}9846a} = 1{,}343P$$

3. $N_{14-11} \Leftarrow \sum Y' = 0$

$$(5{,}333P - P - P - P - 0{,}5P)\cos\alpha + N_{14-11}\cos\beta = 0$$

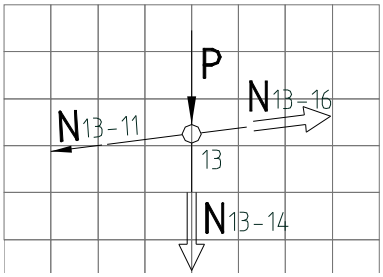
$$b = \sqrt{h_1^2 + \left(\frac{2a}{\cos\alpha} - 2a\sqrt{1-\cos^2\alpha}\right)^2} = 2{,}6578a$$

$$\cos\beta = \frac{h_1}{b} = \frac{1{,}9846}{2{,}6578} = 0{,}7467$$

$$N_{14-11} = -\frac{1.833P \cdot 0{,}9923}{0{,}7467} = -2{,}436P$$

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Узел 13



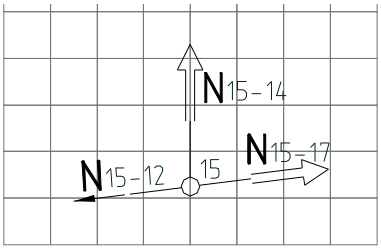
4. $N_{13-14} \Leftarrow \sum Y' = 0$

$N_{13-14} = -P$

5. $N_{13-16} = N_{13-11} \Leftarrow \sum X = 0$

$N_{13-16} = 0{,}504P$

Узел 15

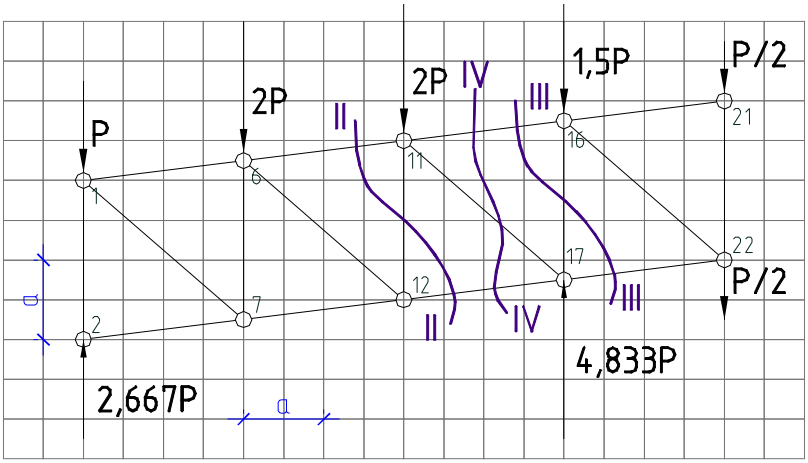


6. $N_{15-14} \Leftarrow \sum Y' = 0$

$N_{15-14} = 0$

7. $N_{15-17} = N_{15-12} \Leftarrow \sum X = 0$

$N_{15-17} = 1{,}343P$



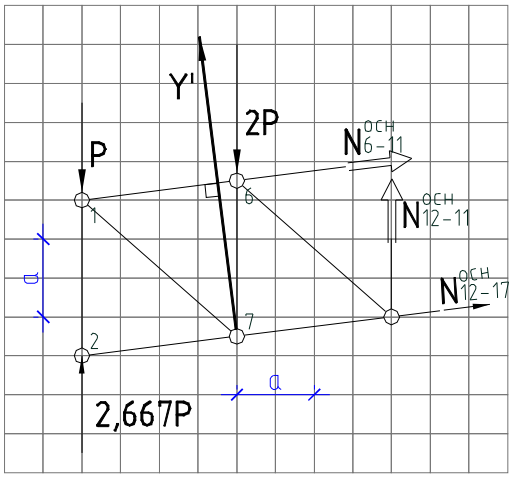
Основная решетка фермы

$N_{12-11} = N^{осн}_{12-11}$ как стержень I категории

$N_{17-16} = N^{осн}_{17-16}$ как стержень I категории

$N_{14-17} = N^{осн}_{17-11}$ как стержень I категории

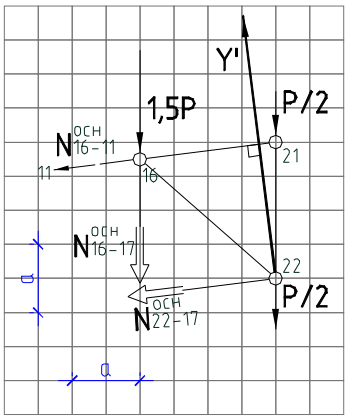
II-II



8. $N^{осн}_{12-11} \Leftarrow \sum Y'^{лев} = 0$

$N^{осн}_{12-11} = 2P + P - 2{,}667P = 0{,}333P$

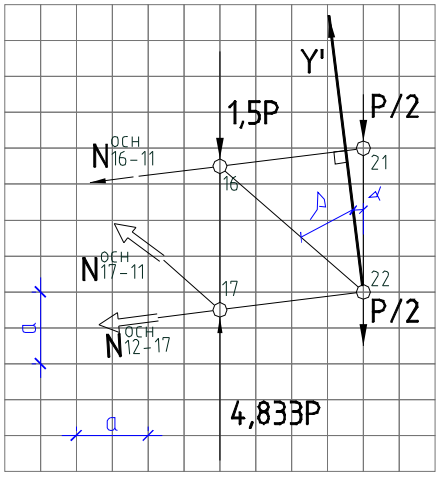
III-III



9. $N_{17-16}^{осн} \Leftarrow \sum Y'^{пр} = 0$

$N_{17-16}^{осн} = -(1{,}5P + 0{,}5P + 0{,}5P) = -2{,}5P$

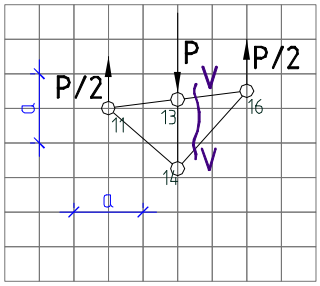
IV-IV



10. $N_{17-11}^{осн} \Leftarrow \sum Y'^{пр} = 0$

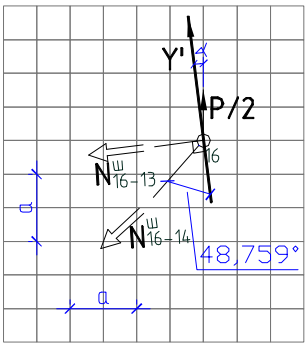
$N_{17-11}^{осн} \cos\beta - (1{,}5 + 0{,}5 + 0{,}5 - 4{,}833)P \cdot \cos\alpha = 0$

$$N_{17-11}^{осн} = -\frac{2{,}333P \cdot \cos\alpha}{\cos\beta} = -\frac{2{,}333 \cdot 0{,}9923P}{0{,}7467} = -3{,}100P$$



Шпренгельная решетка фермы

V-V



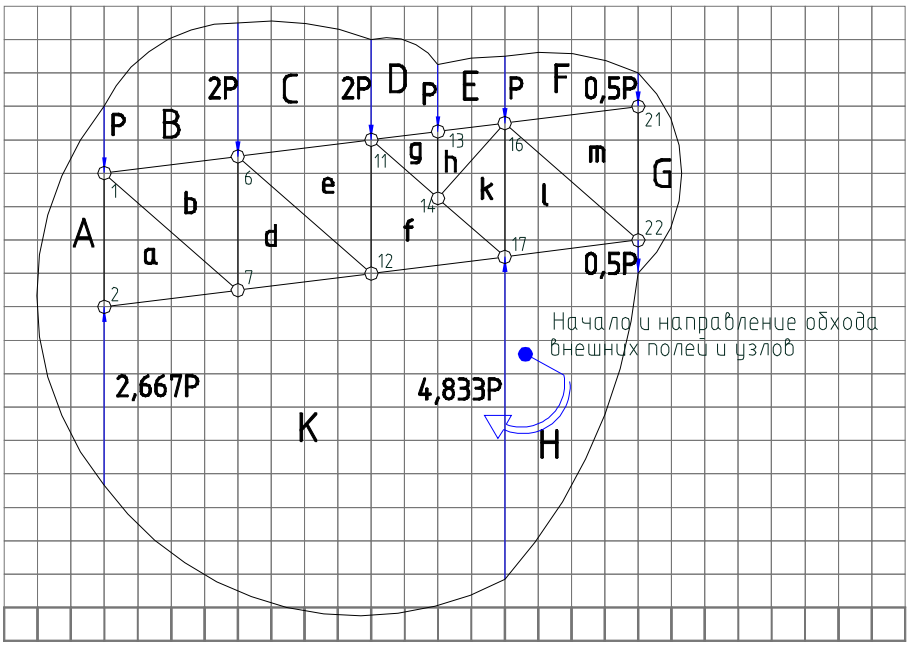
11. $N_{16-14} = N_{16-14}^{ш} \Leftarrow \sum Y' = 0$

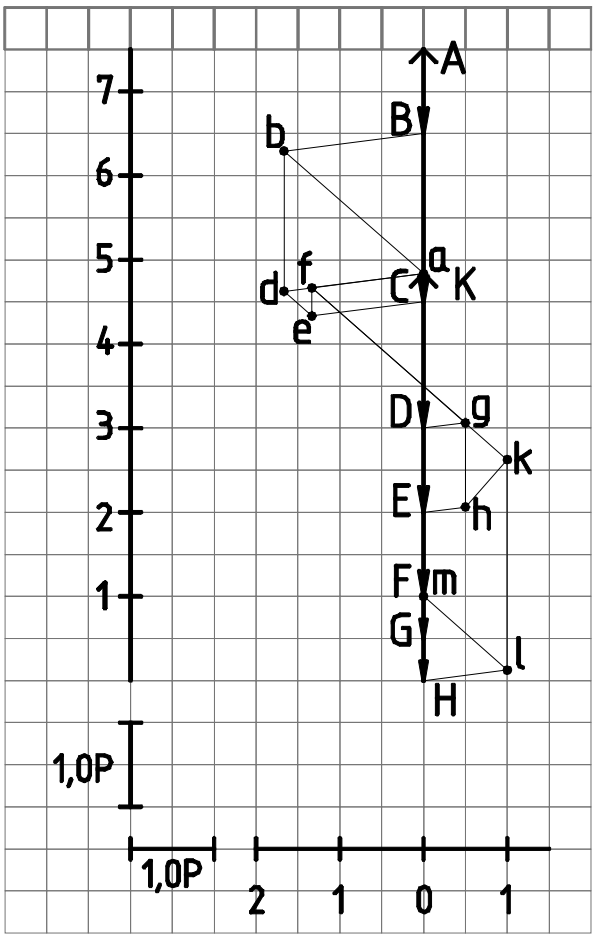
$-N_{16-14}^{ш} \cos 48{,}759^\circ + 0{,}5P\cos\alpha = 0$

$$N_{16-14}^{ш} = \frac{0{,}5P \cdot 0{,}9923}{0.6592} = 0{,}7526P$$

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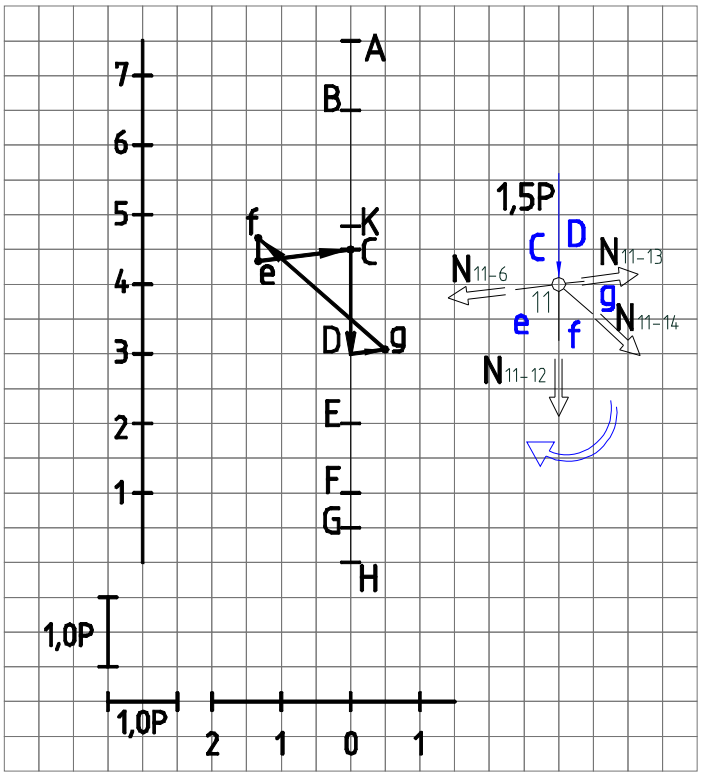
5. Графический метод. Построение диаграммы Максвелла-Кремоны



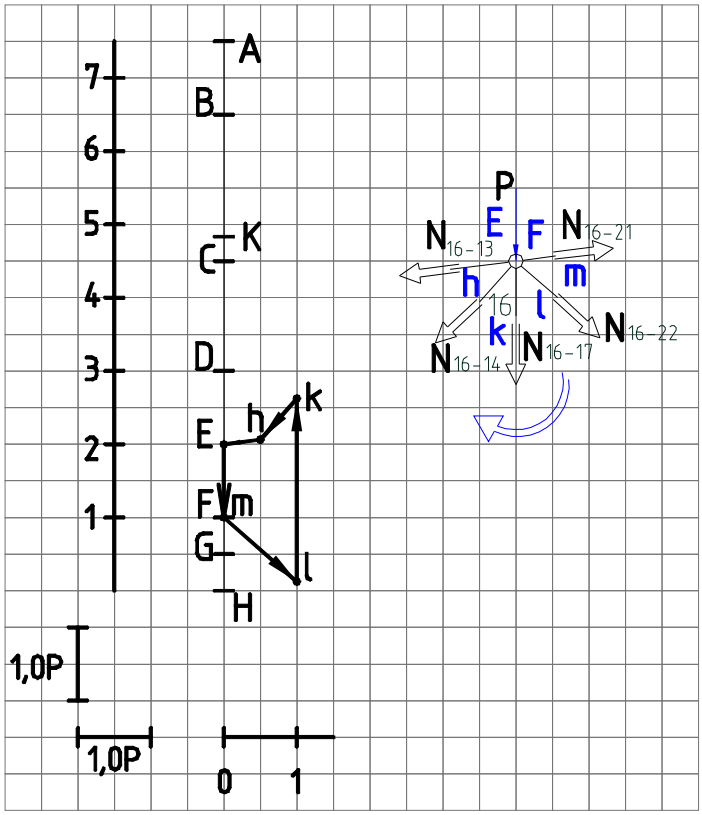


$$|N_{16-14}| = l_{kh} = 0{,}75P$$
$$|N_{17-16}| = l_{kl} = 2{,}5P$$
$$|N^{осн}_{12-11}| = l_{ef} = 0{,}3P$$
$$|N_{17-12}| = l_{Kf} = 1{,}3P$$
$$N_{15-14} = 0$$
$$N_{13-16} = l_{hE} = 0{,}5P$$
$$|N_{13-14}| = l_{gh} = -P$$
$$|N_{14-11}| = l_{gf} = 2{,}4P$$
$$|N_{13-11}| = l_{gD} = 0{,}5P$$

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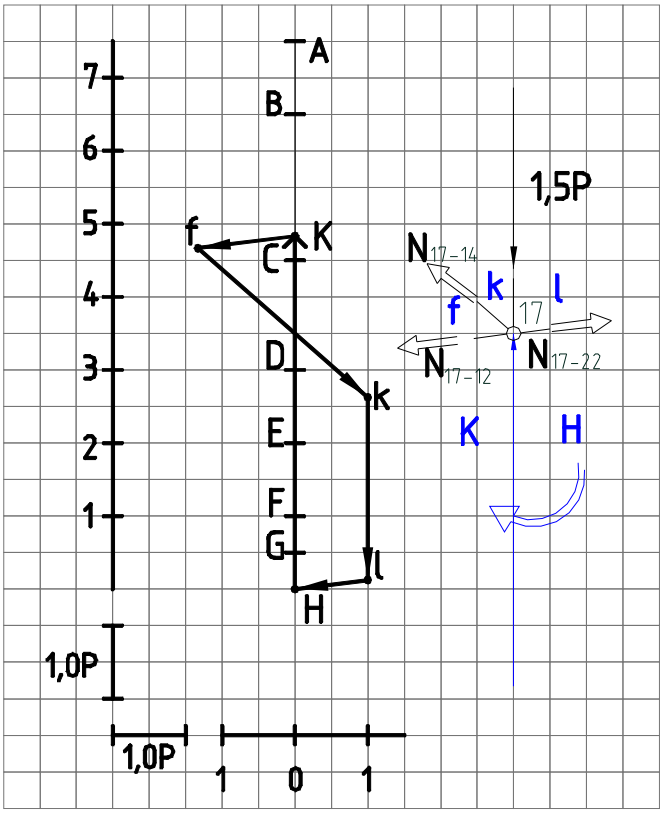


$$N_{11-12}^{осн} = l_{ef} = 0{,}3P$$
$$N_{11-14} = l_{gf} = -2{,}4P$$
$$N_{11-13} = l_{gD} = 0{,}5P$$

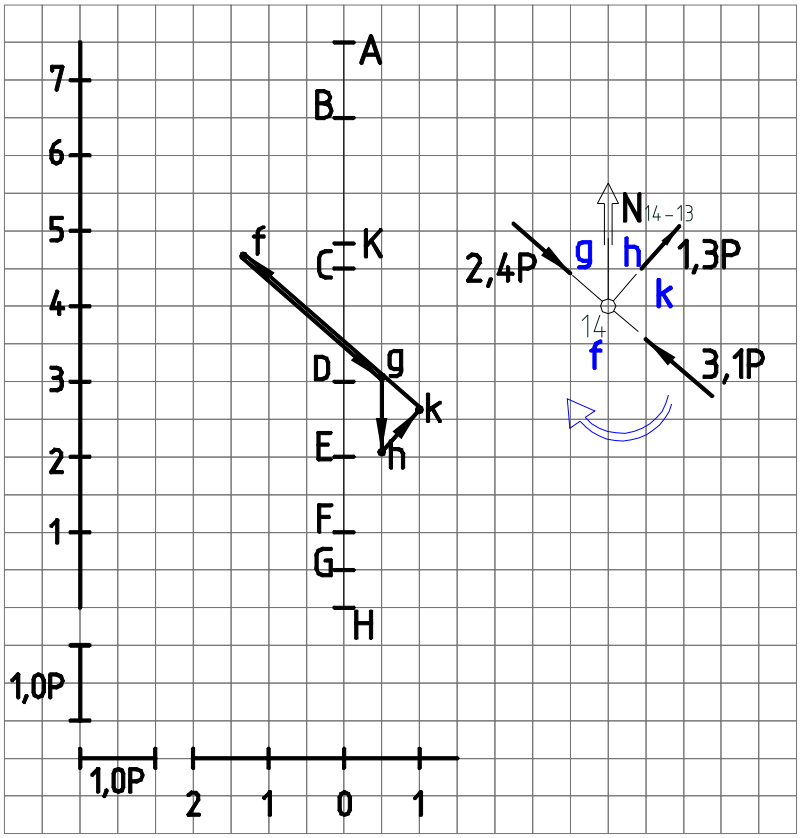


$$N_{16-14} = l_{kh} = 0{,}75P$$
$$N_{16-17} = l_{kl} = -2{,}5P$$
$$N_{16-13} = l_{hE} = 0{,}5P$$

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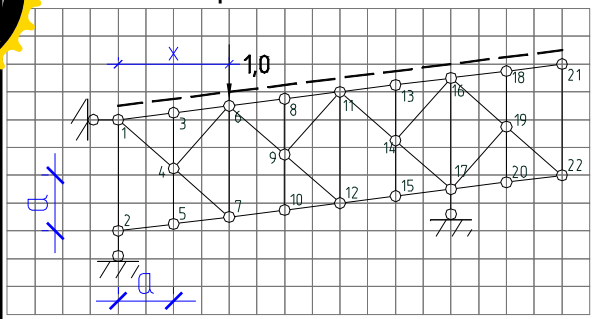
$$N_{17-12} = l_{Kf} = 1{,}3P$$
$$N_{17-14} = l_{kf} = -3{,}1P$$



$$N_{13-14} = l_{gh} = -P$$

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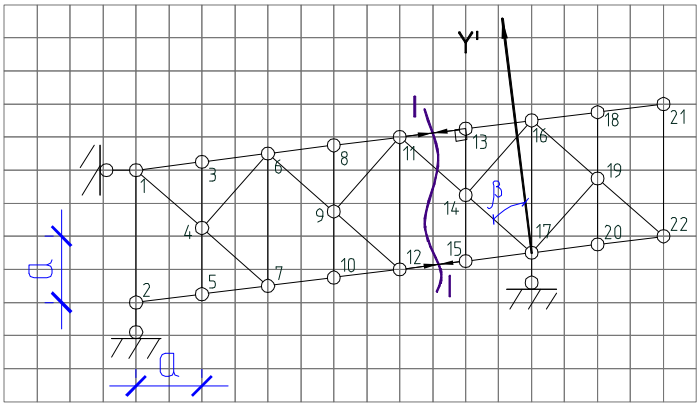
6. Построение линий влияния.

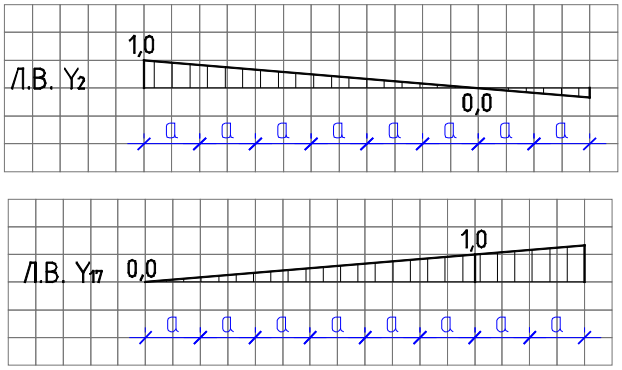


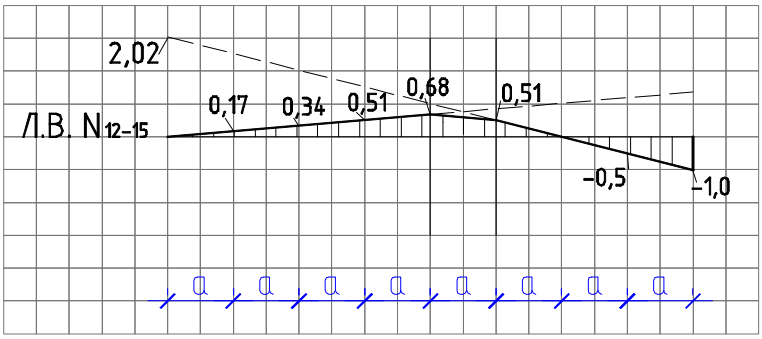
$$h_1 = 2a \cdot \cos\alpha = 2a \cdot \frac{8a}{\sqrt{(8a)^2 + (a)^2}} = 2a \cdot 0{,}9923 = 1{,}9846$$

$$b = \sqrt{h_1^2 + \left(\frac{2a}{\cos\alpha} - 2a\sqrt{1-\cos^2\alpha}\right)^2} = 2{,}6578a\,,$$

$$\cos\beta = \frac{h_1}{b} = \frac{1{,}9846}{2{,}6578} = 0{,}7467$$







$$Л.В.N_{12-15} = Л.В.N_{15-17} = Л.В.N_{12-15}$$

$$N_{15-12}^{осн} \Leftarrow \sum mom_{11}^{пр} = 0$$

$$N_{15-12}^{осн} \cdot h_1 - Y_{17} \cdot 2a = 0$$

$$N_{15-12}^{осн} = \frac{Y_{17} \cdot 2a}{h_1} = 1{,}01Y_{17}\,,$$

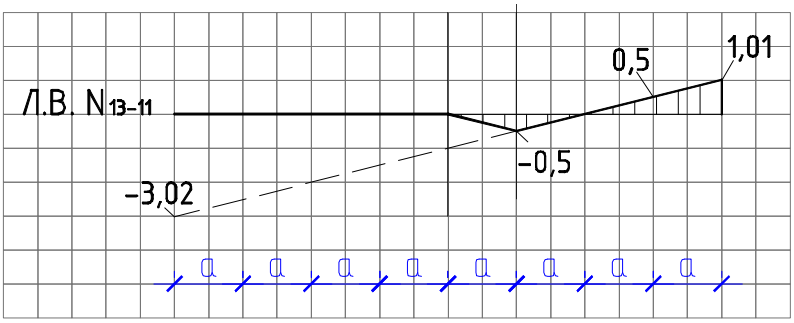
$$0 \le x \le 4a$$

$$N_{12-15}^{осн} \Leftarrow \sum mom_{11}^{лев} = 0$$

$$N_{12-15}^{осн} \cdot h_1 - Y_2 \cdot 4a = 0$$

$$N_{12-15}^{осн} = \frac{Y_2 \cdot 4a}{h_1} = 2{,}02Y_2\,, 6a \le x \le 8a$$

$$N_{12-17} = P(0{,}17 + 0{,}34 + 0{,}51 + 0{,}68 + 0{,}51 - 0{,}5 - 0{,}5) = 1{,}21P$$



$$N_{13-11} \Leftarrow \sum mom_{17}^{пр} = 0$$

$$N_{13-11} \cdot h_1 = 0 \Rightarrow N_{13-11} = 0\,,$$

$$0 \le x \le 4a$$

$$N_{11-13} \Leftarrow \sum mom_{17}^{лев} = 0$$

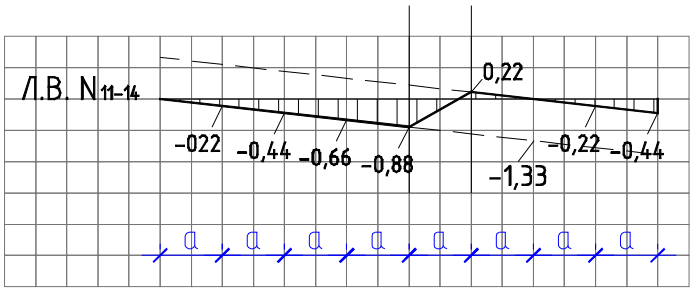
$$N_{11-13} \cdot h_1 + Y_2 \cdot 6a = 0$$

$$N_{11-13} = -\frac{Y_2 \cdot 6a}{h_1} = -3{,}02Y_2\,,$$

$$5a \le x \le 8a$$

$$N_{11-13} = P\left(-0{,}5 + 0{,}5 + \frac{1{,}01}{2}\right) = 0{,}51P$$

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$$N_{14-11} \Leftarrow \sum Y'^{пр} = 0$$

$$Y_{17}\cos\alpha + N_{14-11}\cos\beta = 0$$

$$N_{14-11} = -\frac{Y_{17}\cos\alpha}{\cos\beta} = -1{,}33Y_{17},$$

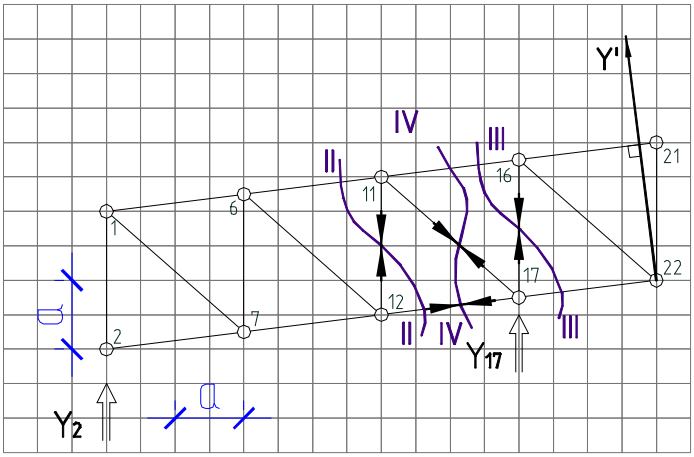
$$0 \le x \le 4a$$

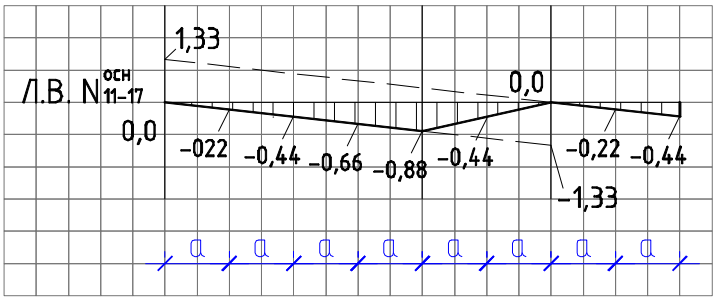
$$N_{11-14} \Leftarrow \sum Y'^{лев} = 0$$

$$Y_{17}\cos\alpha - N_{11-14}\cos\beta = 0$$

$$N_{14-11} = \frac{Y_{17}\cos\alpha}{\cos\beta} = 1{,}33Y_2,\ 5a \le x \le 8a$$

$$N_{17-11} = P(-0{,}22 - 0{,}44 - 0{,}66 - 0{,}88 + 0{,}22 - 0{,}22 - 0{,}44) = -2{,}64P$$





$$Л.В.N_{14-17} = Л.В.N^{осн}_{11-17}$$

$$N^{осн}_{17-11} \Leftarrow \sum Y'^{пр} = 0$$

$$Y_{12}\cos\alpha + N_{17-11}\cos\beta = 0$$

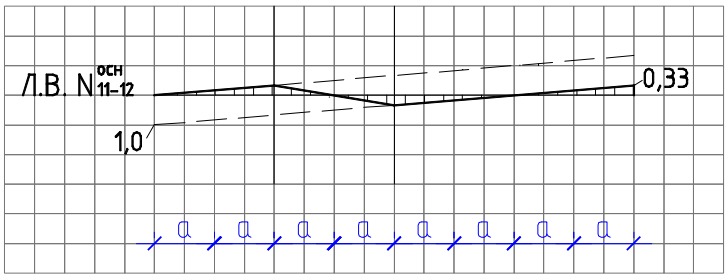
$$N^{осн}_{17-11} = -\frac{Y_{12}\cdot\cos\alpha}{\cos\beta} = -1{,}33Y_{12}, 0 \le x \le 4a$$

$$N^{осн}_{11-17} \Leftarrow \sum Y'^{лев} = 0$$

$$Y_2\cos\alpha - N_{17-11}\cos\beta = 0$$

$$N^{осн}_{17-11} = \frac{Y_2\cdot\cos\alpha}{\cos\beta} = 1{,}33Y_2, 6a \le x \le 8a$$

$$N_{17-11} = P(-0{,}22 - 0{,}44 - 0{,}66 - 0{,}88 - 0{,}44 - 0{,}22 - 0{,}44) = -3{,}3P$$



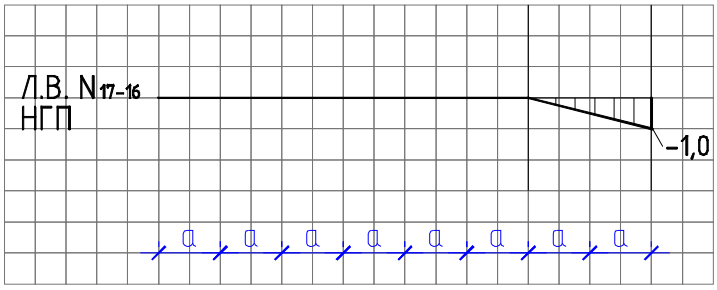
$$N^{осн}_{12-11} \Leftarrow \sum Y'^{лев} = 0$$

$$N^{осн}_{12-11} = -Y_2, 4a \le x \le 8a$$

$$N^{осн}_{11-12} \Leftarrow \sum Y'^{пр} = 0$$

$$N^{осн}_{11-12} = Y_{12}, 0 \le x \le 2a$$

$$N_{11-12} = P\left(\frac{1}{6} + \frac{2}{6} - \frac{1}{6} - \frac{2}{6} + \frac{1}{6} + \frac{2\cdot 0{,}5}{6}\right) = 0{,}33P$$



$$Л.В.N_{17-16} = Л.В.N^{осн}_{17-16}$$

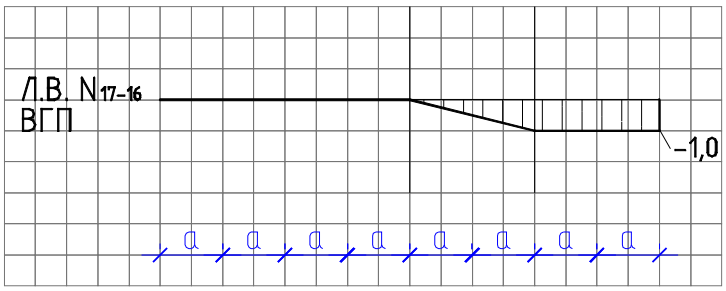
$$N^{осн}_{16-17} \Leftarrow \sum Y'^{пр} = 0$$

$$N^{осн}_{16-17} = 0\,,\, 0 \le x \le 6a$$

$$N^{осн}_{17-16} \Leftarrow \sum Y'^{лев} = 0$$

$$N^{осн}_{17-16} + Y_2 + Y_{12} = 0$$

$$N^{осн}_{17-16} = -Y_2 - Y_{12}\,,\, x = 8a \quad \text{НГП}$$



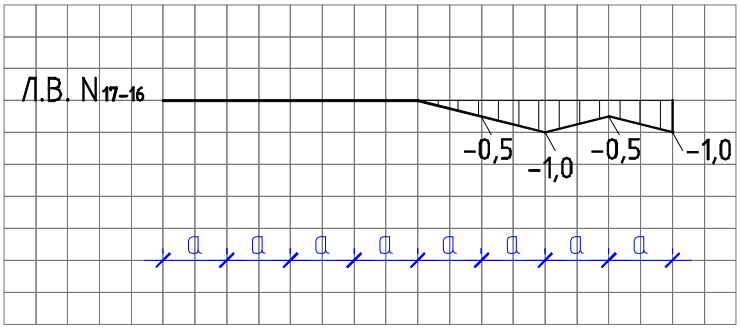
$$N^{осн}_{16-17} \Leftarrow \sum Y'^{пр} = 0$$

$$N^{осн}_{16-17} = 0\,,\, 0 \le x \le 4a$$

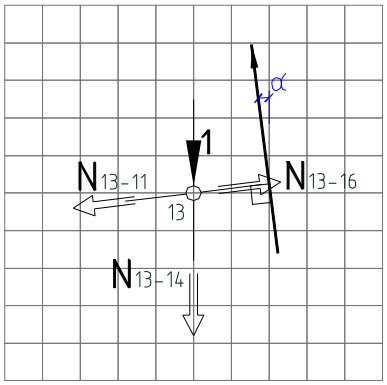
$$N^{осн}_{16-17} \Leftarrow \sum Y'^{лев} = 0$$

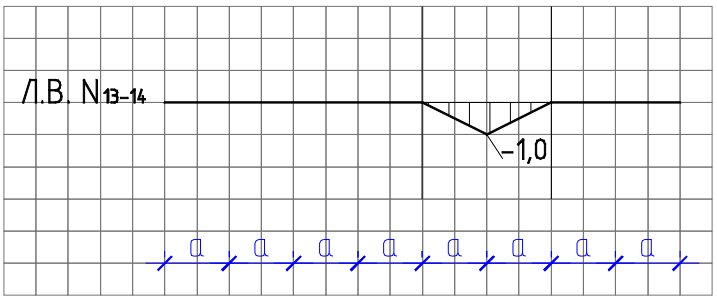
$$N^{осн}_{17-16} + Y_2 + Y_{12} = 0$$

$$N^{осн}_{17-16} = -Y_2 - Y_{12}\,,\; 6a \le x \le 8a \quad \text{ВГП}$$



$$N_{17-16} = -P(0{,}5 + 1 + 0{,}5 + 0{,}5 \cdot 1) = -2{,}5P$$

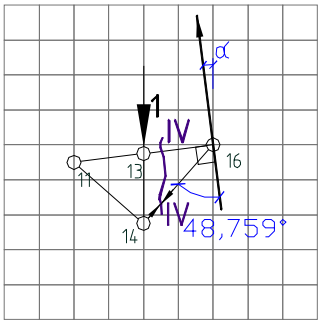


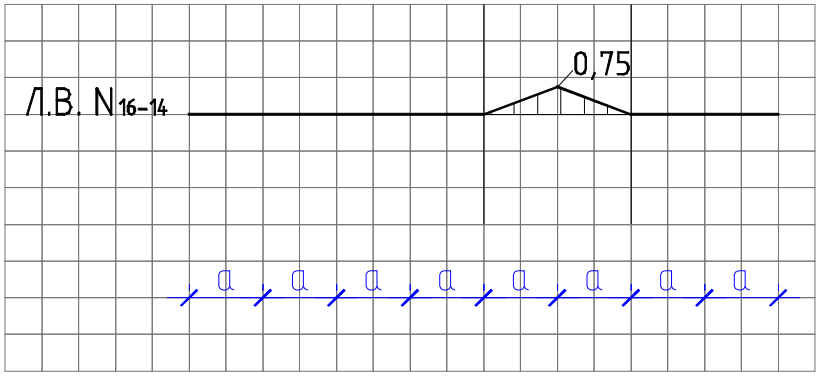


$$N_{13-14} \Leftarrow \sum Y' = 0$$

$$N_{13-14} = -1\,,\; x = 5a$$

$$N_{13-14} = -P$$





$$N_{16-14} = N^{ш}_{16-14} \Leftarrow \sum Y' = 0$$

$$N^{ш}_{16-14}\cos 48{,}759^{\circ} - 0{,}5\cos\alpha = 0$$

$$N^{ш}_{16-14} = \frac{0{,}9923}{0{,}6592} = 0{,}75\,,\ x = 5a$$

$$N^{ш}_{16-14} = 0{,}75P$$

7. Таблица результатов

№ стержня	11-13 / 13-16	12-15 / 15-17	11-14	13-14	14-15	11-12	16-17	14-17 / 11-17 (осн)	14-16
Аналитический	0,504P	1,343P	-2,436P	-P	0	0,333P	-2,5P	-3,1P	0,753 P
Графический	0,5P	1,3P	-2,4P	-P	0	0,3P	-2,5P	-3,1P	0,75P
Линии влияния	0,51	1,21P	-2,64	-P	0	0,33P	-2,5P	-3,3P	0,75P
Знак усилия	+	+	-	-		+	-	-	+